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DESCRIPTION

Reflow Soldering Method Using Pb-free Solder Alloy, and Hybrid Mounting Method and Structure

Technical Field

The present invention relates to a reflow soldering method using a Pb-free solder alloy with less toxicity, and a hybrid mounting method, as well as a hybrid mounting structure.

Background Art

When an electronic component is mounted by soldering on a circuit board such as an organic board, use of a Pb-free solder alloy with less toxicity has been demanded.

The prior art relating to the mounting method using Pb-free solder is known from JP-A-10-166178 (prior art 1), JP-A-11-179586 (prior art 2), JP-A-11-221694 (prior art 3), JP-A-11-354919 (prior art 4), JP-A-2001-168519 (prior art 5), JP-A-2003-46229 (prior art 6), etc.

The prior art 1 describes, as the Pb-free solder, an Sn-Ag-Bi series solder or an Sn-Ag-Bi-Cu series solder alloy. The prior art 2 describes connection of the Sn-Ag-Bi series solder effective as the Pb-free solder with an electrode provided on its surface with an Sn-Bi series layer. The prior art 3 describes reflow soldering of an electronic component to

each of both surfaces of an organic board having a first surface and a second surface by Pb-free solder comprising Sn as a main ingredient, from 0 to 65 mass% of Bi, from 0.5 to 4.5 mass% of Ag, from 0 to 30 mass% in total of Cu or/and In. The prior art 4 describes a method of connecting an electronic component and a circuit board using Pb-free solder containing Bi, in which the solder is cooled at a cooling rate of about 10 to 20°C/s. The prior art 5 discloses a method of mounting an electronic component by surface connection at the A surface of a board by reflow soldering, then connecting and mounting leads of an electronic component inserted from the side of the A surface by flow soldering to an electrode on the B surface of the board. In this method, solder used for reflow soldering on the A surface is Pb-free solder with a composition: Sn-(1.5-3.5 wt%)Ag-(0.2-0.8 wt%)Cu-(0-4 wt%)In -(0-2 wt%)Bi. In addition, the solder used for flow soldering on the side of the B surface is Pb-free solder with a composition: Sn-(0-3.5 wt%)Ag-(0.2 to 0.8 wt%)Cu. The prior art 6 describes a hybrid mounting method using Pb-free solder in which peeling of a surface mounted component by re-melting of the solder at the connection portion of the surface mounted component is prevented by conducting flow soldering while cooling the upper surface of circuit board. Further, the prior art 6 describes the use of Sn-(1-4)Ag-(0-8)Bi-(0-1)Cu (unit: mass%) as a solder alloy for the reflow solder paste

and the use of Sn-3Ag-0.5Cu or Sn-0.8Ag-57Bi (unit: mass%) approximate to an eutectic composition as a flow solder.

Disclosure of Invention

Meanwhile, a hybrid mounting method using Pb-free solder has recently needed to reflow solder a low heat resistant electronic component such as FPGA (Field Programmable Gate Array) with a heat resistant temperature of 220°C for a component main body to the surface of a circuit board.

Further, the hybrid mounting method needs to reflow solder the low heat resistant electronic component on the surface of the circuit board and flow solder the same to leads of an electronic component inserted from the surface of the circuit board by using Pb-free solder. Also during the flow soldering, it is necessary to prevent peeling of the low resistant electronic component by the re-melting of the reflow solder and not to degrade reliability after soldering connection.

However, the prior arts 1 to 6 described above do not take into sufficient consideration the hybrid mounting method that meets such necessary subjects by using the Pb-free solder.

An object of the present invention is to provide a reflow soldering method using a Pb-free solder alloy for attaining reflow soldering of a low heat resistant electronic

component such as FPGA (Field Programmable Gate Array) in order to solve the foregoing problems.

Further, another object of the invention is to provide a hybrid mounting method by using a Pb-free solder alloy capable of attaining reflow soldering of a low heat resistant electronic component such as FPGA and maintaining reliability for the connection strength of the reflow soldered portion upon flow soldering, and a system therefor, as well as a hybridly mounted structure.

To achieve the objects described above, the invention provides a reflow soldering method using a Pb-free solder alloy characterized by soldering a surface mounting component to the upper or lower surface of a circuit board by using a Pb-free solder paste comprising an alloy based on Sn-(1-4)Ag-(0-1)Cu-(7-10)In (unit: mass%).

Further, the invention is characterized in that the lead of the surface mounting component is subjected to Pb-free plating. Further, the invention is characterized in that the Pb-free plating is Sn plating or Sn-Bi plating.

Further, the present invention provides a hybrid mounting method using Pb-free solder, characterized by comprising: a low temperature reflow soldering step of soldering a surface mounting component including a low heat resistant electronic component (heat resistant temperature of about 220°C or lower) such as FPGA to at least the upper

surface of a circuit board by using an In incorporated low melting point Pb-free solder; an insertion step of inserting the lead or terminal of the insertion mounting component into a through hole perforated through the circuit board from the upper surface; a flux coating step of inserting the lead or terminal of the insertion mounting component in the through hole by the insertion step and then coating flux to the circuit board; a pre-heating step of pre-heating the lower surface of the circuit board after coating the flux to the circuit board in the flux coating step; and a flow soldering step of applying a jet flow of high-melting Pb-free solder such as Sn-Cu series or Sn-Ag series solder having high reliability to the lower surface of a circuit board while cooling the upper surface of the circuit board which has been pre-heated at the lower surface thereof in the pre-heating step, thereby flow soldering the lead or terminal of the insertion mounting component to the circuit board.

In particular, the In-incorporated low melting Pb-free solder paste used in the low temperature reflow soldering step in the invention is an alloy based on a series in which In is incorporated into Sn-Cu series, Sn-Ag series, Sn-Ag-Cu-series or Sn-Ag-Bi series, preferably, Sn-(1-4)Ag-(0-1)Cu-(4-10)In (unit: mass%).

The reason of adding In (4-10 mass%) to the alloy is that unlike Bi, In has higher solid solubility to Sn as a base

metal for the solder and is less likely to precipitate in the solder when it is cooled to room temperature from a molten state during soldering. Further, it has a property of finely dispersing in the solder if precipitation occurs and causing less segregation on the high temperature side even when the solder is not cooled uniformly during cooling of the solder to have a temperature gradient as in the case of Bi. Since the connection strength with the connection portion lowers remarkably if segregation occurs, it is necessary to completely suppress the occurrence of segregation.

Further, in a case of reflow soldering the surface mounting component including the low heat resistant electronic component (heat resistant temperature of about 220°C) by using a reflow furnace, since the heat capacity, the reflectivity to infrared rays, etc. are different depending on the components, temperature scatters in the circuit board mounting the components. It is known that the temperature scatters up to as much as 15°C depending on the circuit board. Further, most of the low heat resistant electronic components (heat resistant temperature of 220°C) have small heat capacity and reduced size and they reach the highest temperature in the board upon reflow soldering in most cases. On the other hand, a solder paste-supplied place on the circuit board includes such a place as BGA (Ball Grid Array), etc. where a hot blow of the reflow furnace less intrudes between the component main

body and the circuit board. In this case, such a place is at the lowest temperature in the circuit board when reflow soldering is performed.

Accordingly, in a case of reflow soldering the low heat resistant electronic component to the circuit board, it is necessary that the reflow solder paste is melted at about 205°C (= 220 - 15) at the lowest and this needs incorporation of In by about 7 to 10 mass% to the Sn-(1-4)Ag-(0-1)Cu series solder.

With the reasons as described above, the reflow solder paste is an alloy based on Sn-(1-4)Ag-(0-1)Cu-(7-10)In (unit: mass%) in order to attain reflow soldering the low heat resistant electronic component and completely suppress the occurrence of segregation to prevent remarkable lowering of the connection strength at the connection portion.

Further, according to the invention, the Pb-free solder paste in the flow soldering step has an eutectic composition such as Sn-Cu series, Sn-Ag series, Sn-Ag-Cu series, Sn-Ag-Bi series or a series with addition of In or a composition approximate to the eutectic composition. In particular, Sn-3Ag-0.5Cu-xIn ($0 \leqq x \leqq 9$, unit; mass%) has an Sn-Ag-Cu series eutectic composition or a composition approximate to the eutectic composition and, in addition, it has a higher melting point than the melting point of 183°C of the existent Sn-37Pb and can be used under extreme conditions while having high

connection reliability. Further, Sn-0.8Ag-57Bi has an eutectic composition or a composition approximate to the eutectic composition and can be used while having high connection reliability in a case of use under restriction of the using temperature.

Then, in the flow soldering step, it is necessary that the temperature of the jet flow of the Pb-free solder applied to the lower surface of the circuit board is within a range from 170°C to 260°C. This is because the solder is sufficiently wetted to the board electrode at the temperature.

Further, Pb contained in the existent plating in the electrode for the surface mounting component contains a great amount of ingredients that produces other low temperature eutectic compositions greatly deviated from a solder composition (eutectic composition) at the connection portion after reflow soldering. Therefore, the contained low temperature eutectic composition melts preferentially upon re-melting of the solder at the reflow connection portion under the thermal effect of the molten solder upon flow soldering (170°C to 260°C) and the composition tends to be concentrated to a higher temperature portion so as to promote occurrence of segregation.

Accordingly, it is desirable that the plating for the electrode of the surface mounting component also have a Pb-free composition, and the composition preferably comprises

constituent elements of a solder alloy used for surface mounting such as pure Sn (melting point: 232°C). Further, it is considered that Sn with addition of a slight amount of Bi is preferred for a component where occurrence of whiskers (whisker crystals) is remarkable.

Further, according to the invention, to prevent the peeling of the low heat resistant electronic components by the re-melting of the In-incorporated low melting reflow solder in the flow soldering step, it is preferred to blow or spray a fluid such as nitrogen at 50°C or lower (within a range from 20°C - 50°C) to the upper surface of the circuit board at a flow rate of about 0.3 to 1.2 m^3/min (preferably about from 0.5 to 1.2 m^3/min) thereby conducting cooling since this can extend the upper limit of the allowable range for the melting temperature of the flow solder. However, rise of the solder into the small diameter through holes or into the through holes in which large capacity insertion mounting components are inserted upon flow soldering to the circuit board is sometimes restricted failing to obtain a sufficient connection strength after the solidification of the solder. Therefore, it is desirable that the fluid be not used greatly exceeding the flow rate (1.2 m^3/min).

Further, according to the invention, the upper limit of the allowable melting temperature range of the flow solder can be extended by bringing a heat dissipation jig into contact

with the lead of the surface mounting electronic component while blowing a fluid such as nitrogen at 50°C or lower (within a range from 20°C to 50°C) to the upper surface of the circuit substrate in the flow soldering step.

As has been described above, the invention can provide an effect of performing reflow soldering of a low heat resistant electronic component such as FPGA to a circuit substrate by using a Pb-free solder alloy.

Further, the invention can provide an effect of performing hybrid mounting while preventing defects of soldering caused by making the solder Pb-free and while maintaining high reliability by conducting reflow soldering of surface mounting components including the low heat resistant electronic component such as FPGA to the circuit board and flow soldering of the insertion mounting components to the circuit board by using a Pb-free solder alloy.

Further, the invention can provide an effect of facilitating the temperature control in the hybrid mounting of surface mounting components including the low heat resistant electronic component such as FPGA and insertion mounting components by using the Pb-free solder alloy since the allowable range of the temperature for the jet flow of the molten solder can be extended to a high temperature side upon flow soldering.

Brief Description of Drawings

FIG. 1 is a view for explaining a first example of a hybrid mounting method using Pb-free solder according to the present invention.

FIG. 2 is a view for explaining second and third examples of a hybrid mounting method using Pb-free solder according to the present invention.

FIG. 3 illustrates the state of attaching (mounting) a heat dissipation jig to QFP as a fourth example according to the invention.

FIG. 4 illustrates a breaking condition for a QFP-LSI connection portion in the first example according to the invention.

FIG. 5 illustrates a breaking condition for a QFP-LSI connection portion in the second example according to the invention.

FIG. 6 illustrates a breaking condition for a QFP-LSI connection portion in the third example according to the invention.

FIG. 7 illustrates a breaking condition for a QFP-LSI connection portion in the fourth example according to the invention.

FIG. 8 illustrates a breaking condition for a QFP-LSI connection portion in a fifth example according to the invention.

FIG. 9 illustrates a breaking condition for a QFP-LSI connection portion in a sixth example according to the invention.

FIG. 10 illustrates a breaking condition for a QFP-LSI connection portion in a seventh example according to the invention.

FIG. 11 is a view showing a breaking condition for a QFP-LSI connection portion in a comparative example according to the invention.

Best Mode for Carrying Out the Invention

Embodiments of the present invention are to be described specifically with reference to the drawings.

In the invention, hybrid mounting is conducted as below. Surface mounting components 2, 4a including a low heat resistant electronic component (heat resistant temperature of about 220°C or lower) such as FPGA (Field Programmable Gate Array) are soldered to an upper surface 101 of a circuit board 1 such as an organic board by using an In-incorporated low melting Pb-free solder paste 11 as shown in FIG. 1. A lead 12 of an insertion mounting component 5 is inserted into a through hole, etc. from the upper surface of the circuit board 1. Then flux is coated to the circuit board 1 and flow soldering is conducted by a jet flow 3 of the Pb-free molten solder from a lower surface 102 of the circuit board 1. In

the flow soldering, to shorten time taken to be soldered to the circuit board 1, the lower surface 102 of the circuit board 1 is pre-heated by a pre-heating device 22 such as a sheath heater. Then, flow soldering is conducted by a jet flow 3 of a Pb-free molten solder from the lower surface 102 of the circuit board 1, and both surfaces of the circuit board 1 are cooled immediately after soldering.

The low heat resistant electronic component 2 such as FPGA mounted to the upper surface 101 of the circuit board 1 generally has smaller heat capacity and the temperature thereof tends to increase compared with other surface mounting electronic components.

In view of the above, in a usual reflow furnace, the component main body of the low heat resistant electronic component 2 is often the highest temperature portion in the board during reflow soldering. Further, in a case of a BGA (Ball Grid Array) having a structure where the component main body tends to suppress the hot blow from hitting against the solder paste supply portion during reflow soldering, the solder paste supply portion is often the lowest temperature portion in the board. In any case, the low heat resistant electronic component 2 such as FPGA is often constituted of the QFP-LSI or it is also constituted sometimes of the BGA-LSI.

Accordingly, the temperature difference between the component main body of the low heat resistant electronic

component 2 and the solder paste supply portion 11 results in the variations of temperature in the circuit board 1, which is about 15°C at the maximum when the usual reflow furnace is used. Accordingly, in a case where the component main body of the low heat resistant electronic component 2 is 220°C or lower, the solder paste supply portion 11 is naturally at 205°C or lower, and a Pb-free reflow solder paste which melts even at 205°C is necessary.

Then, the In-incorporated low melting Pb-free solder paste 11 is a an alloy material based on Sn-(1-4)Ag-(0-1)Cu-(7-10)In (unit: mass%) that melts even at 205°C.

Further, in a case where the low heat resistant electronic component 2 is constituted of BGA, it is desirable that the solder ball as well as the reflow solder paste have the same composition.

Further, the Pb-free material for the jet flow 3 of the flow solder is an eutectic composition of Sn-Cu series, Sn-Ag series, Sn-Ag-Cu series, Sn-Ag-Bi series or a series with addition of In thereto, or a composition approximate to such eutectic composition. In particular, Sn-3Ag-0.5Cu-xIn ($0 \leqq x \leqq 9$, unit: mass%) has an Sn-Ag-Cu series eutectic composition or a composition approximate to such eutectic composition and, in addition, it has higher melting point than the melting point 183°C of existent Sn-37Pb and can be used even under an extreme condition having high reliability of connection.

Further, Sn-0.8Ag-57Bi has an eutectic composition or a composition approximate to the eutectic composition and in a case of use under restricted using temperature, it can be used at high connection reliability.

Then, in the flow soldering step, it is necessary that the temperature of the Pb-free solder jet flow hitting against the lower surface of the circuit board should be within a range from 170°C to 260°C. This is because the solder is sufficiently wetted at the temperature to the board electrode.

Further, before the flux coating step, a warp preventive jig made of metal such as Al may be optionally attached to the circuit board 1. Further, in a case where the surface mounting component is mounted to the lower surface of the circuit board 1 by reflow soldering, a cover (not illustrated) may be attached to the portion so as to prevent the flow solder from depositing on it.

Further, in the flow soldering, the upper limit of the allowable melting temperature range of the flow solder can be extended in a case of flow soldering by cooling the upper surface 102 of the circuit board 1, as shown in FIG. 2, by blowing a fluid such as nitrogen at 50°C or lower (in a range from 20°C to 50°C) at a flow rate of about 0.3 to 1.2 m^3/min (preferably, from 0.5 to 1.2 m^3/min) by a board cooling device 6. Further, the upper limit of the allowable melting temperature range of the flow solder can be extended further

by bringing a heat dissipation jig made of a metal such as aluminum into contact with the leads of the surface mounting electronic component 2, etc. as shown in FIG. 3.

As described above, even in a case of extending the upper limit of the range for the melting temperature of the flow solder by conducting flow soldering in a state of cooling the upper surface 101 of the circuit board 1 with the board cooling device 6, it is possible to prevent the occurrence of peeling by the re-melting of the In-incorporated low melting Pb-free solder paste 11 at the connection portions for the surface mounting components 2, 4.

[First Example]

In a first example, a generally used glass epoxy board 1a was used as a circuit board 1. The glass epoxy board has a thickness of about 1.6 mm, a length of about 350 mm, and a width of about 350 mm. It is provided on its board surface with a copper foil having a thickness of about 18 μm, and has through holes each having an inner diameter of 1 mm and a Cu pad diameter of about 1.6 mm formed at a density of about 0.7 N/cm^2.

A QFP-LSI 2a of 32 mm square was used as a surface mounting pad 2. It has a lead pitch of about 0.5 mm and a lead width of about 0.2 mm and is provided with 208 leads made of 42 alloy subjected to Sn-10 mass% Pb plating.

Then, the QFP-LSI 2a of 32 mm square was flow soldered to the upper surface of the glass epoxy board 1a by 10 types of In-incorporated solder pastes of Sn-3Ag-0.5Cu-xIn ($0 \leqq x \leqq 9$, unit: mass%) (details are shown in the following Table 1).

Table 1

Solder composition (mass%)	Solidus temperature (°C)	Liqiudus temperature (°C)
Sn-3Ag-0.5Cu	217	220
Sn-3Ag-0.5Cu-1In	207	219
Sn-3Ag-0.5Cu-2In	206	218
Sn-3Ag-0.5Cu-3In	205	217
Sn-3Ag-0.5Cu-4In	204	216
Sn-3Ag-0.5Cu-5In	202	215
Sn-3Ag-0.5Cu-6In	200	213
Sn-3Ag-0.5Cu-7In	198	211
Sn-3Ag-0.5Cu-8In	195	210
Sn-3Ag-0.5Cu-9In	193	209

As apparent from Table 1, at 7 mass% of In, the solidus temperature is 198°C and liquidus temperature is 210°C and melting occurs near 205°C. Accordingly, by incorporating In by 7 mass% or more, a low heat resistant electronic component (heat resistant temperature of about 220°C or lower) 2 such as FPGA can be reflow soldered on the surface of the circuit board 1.

However, in a case where In is incorporated in excess of 10 mass%, since segregation occurs during cooling of the solder to remarkably deteriorate the connection strength of the connection portion, it is necessary to define the In

content to 10 mass% or less.

Then, six 6-terminal connectors 5a with 2.54 mm pitch having 0.5 mm square terminal (lead) 11a subjected to Sn-10 mass% Pb plating were inserted to through holes (not illustrated) of the circuit board 1 from the upper surface of the board on the side of the board sample where the four QFP-LSI 2a were connected thereto.

Then, the lower surface 102 of the circuit board 1 was pre-heated using a sheath heater having a highest power of 9 kW to elevate the temperature of 25°C (normal temperature) at the lower surface 102 of the circuit board 1a to 118°C for the highest portion and 100°C for the lowest portion in one minute. Then, a jet flow 3a of solder of Sn-3Ag-0.5Cu (unit: mass%) or Sn-0.8Ag-57Bi (unit: mass%) approximate to an eutectic composition was blown to the lower surface 102 of the board 1a in a state not cooling the upper surface 101 of the circuit board 1 by the board cooling device 6 and 6-terminal connectors 5a were soldered without cooling by the board cooling device 6 as shown in FIG. 1 to manufacture a board sample. In this case, the molten solder in the flow soldering bath (not illustrated) was Sn-0.8Ag-57Bi, Sn-0.7Cu or Sn-3Ag-0.5Cu and the temperature of the flow soldering bath was set to several conditions such that the temperature was 170 to 260°C.

The samples described above were observed whether

breakage occurred or not in the connection portion of the QFP-LSI 2a.

FIG. 4 shows the results of an experiment for ten types of In-incorporated solder pastes in which the composition of the reflow solder material is Sn-3Ag-0.5Cu-xIn ($0 \leqq x \leqq 9$, unit: mass%) according to the invention. FIG. 11 shows the results of an experiment for 9 types of Bi-incorporated solder pastes in which the composition of the reflow solder material is Sn-3Ag-0.5Cu-xBi ($0 \leqq x \leqq 8$, unit: mass%) as a comparative example.

In each graph, the temperature of the molten solder in the flow soldering bath is indicated on the abscissa and the content for Bi, In in the solder used for the connection of QFP-LSI is indicated on the ordinate, and the condition not causing breakage is shown by symbol "○" and the condition causing the breakage was shown by symbol "X".

Further, the solid line in each of the graphs is a line considered to be a boundary between the conditions causing breakage and the conditions not causing breakage. To compare the results of the experiment according to the invention and those of the comparative example in FIG. 11, the boundary in FIG. 11 is shown by a dotted line in FIG. 4.

As shown in FIG. 4, also in the results of the experiment not cooling the upper surface 101 of the board 1a, it has been found that by using Sn-3Ag-0.5Cu-xIn according to

the invention for the paste 11 for the connection of QFP-LSI 2a, breakage less occurred at the connection portion and the allowable temperature range of the molten solder can be extended more in the flow soldering compared with the case of the comparative example using Sn-3Ag-0.5Cu-xBi.

That is, the experiment confirms that peeling by segregation of the surface mounting component upon flow soldering can be suppressed by adding In to the Sn-Ag-Cu series as in the invention as the composition of the reflow solder for use in surface mounting.

Further, the results of the experiment shown in FIG. 4 confirm that the temperature of the molten flow solder can be extended to 235°C at the In content of 7 mass% and the temperature of the flow melt soldering can be extended to 230°C at the content of In from 8 to 9 mass%.

[Second Example]

A second example is different from the first example in that a fluid such as nitrogen was blown to the upper surface 101 of the circuit board 1 for cooling as shown in FIG. 2 at about 20°C to 50°C at a flow rate of about 0.5 m^3/min. In FIG. 5, the temperature of the molten solder in the flow soldering bath is indicated on the abscissa and the In content of the solder used for the connection of QFP-LSI is indicated on the coordinate, and conditions causing no breakage is shown by

symbol "○" and the condition causing breakage is shown by symbol "X". Further, the solid line in FIG. 5 is a line to be considered as a boundary between the conditions causing breakage and the conditions not causing the breakage.

The results of an experiment in the second example as shown in FIG. 5 confirm that the upper limit of the temperature of the flow molten solder can be increased by about 10°C or less compared with the first example shown in FIG. 4. Further, the results of the experiment shown in FIG. 5 confirm that the temperature of the molten flow solder can be extended to 245°C at the In content of 7 mass%, the temperature of the flow melting solder can be extended to 240°C at the In content of 8 mass% and the temperature of the flow melting solder can be extended to 235°C at an In content of 9 mass%.

[Third Example]

In a third example, as shown in FIG. 2, a fluid such as nitrogen at about 20°C to 50°C was blown for cooling at a flow rate of about 1.2 m^3/min by a board cooling device 6 in the second example. In FIG. 6, the temperature of the molten solder in the flow soldering bath is indicated on the abscissa and the In content in the solder used for the connection of QFP-LSI is indicated on the abscissa, and the condition not causing breakage is indicated by symbol "○" and the condition

causing the breakage is indicated by the symbol "X". Further, the solid line in FIG. 6 is a line considered to be a boundary between the conditions causing breakage and the conditions not causing the same.

The results of the experiment for the third example as shown in FIG. 6 confirm that the upper limit for the allowable melting temperature of the flow solder can be increased by about 15°C compared with the first example shown in FIG. 4. Further, the results of the experiment shown in FIG. 6 confirm that the allowable melting temperature of the flow solder can be extended to 250°C at the In content of 7 mass%, the allowable melting temperature of the flow solder can be extended to 245°C at the In content of 8 mass%, and that the allowable melting temperature of the flow solder can be extended to 240°C at the In content of 9 mass%.

In view of the foregoing results, in a case of increasing the blowing amount of the fluid such as nitrogen to about 1.2 m^3/min, reflow soldering can be conducted by using the Sn-Ag-Cu molten solder, etc. at 240 to 250°C even in a case of adding In by about 7 to 9% to the reflow solder for the surface mounting components.

[Fourth Example]

In a fourth example, as with the cases of the second and third examples, when flow soldering was performed, with

the board cooling device 6 being operated, a heat dissipation jig 7 was mounted to the connection portion for the surface mounting component (32 mm square QFP-LSI) for reflow soldering. This jig 7 is formed of a square frame made of metal such as aluminum. The jig 7 was then brought into contact with the leads of the surface mounting component 2 to cool the upper surface 101 of the circuit board 1. Thus, the effect was improved of suppressing peeling by segregation for the surface mounting component upon flow soldering. In this case, the flow melting solder was Sn-0.7Cu or Sn-3Ag-0.5Cu, and the temperature of the flow soldering bath was set to several conditions such that the temperature was 250 to 280°C.

In FIG. 7, the temperature of the molten solder in the flow soldering bath is indicated on the abscissa and the In content in the solder used for the connection of QFP-LSI is indicated on the abscissa, and the condition not causing breakage is indicated by symbol "○" and the condition causing breakage is indicated by the symbol "X". Further, the solid line in FIG. 7 is a line considered to be a boundary between the conditions causing breakage and the conditions not causing the same.

The results of the experiment for the fourth example as shown in FIG. 7 confirm that the upper limit for the allowable melting temperature of the flow solder can be increased by about 20°C compared with the first example shown in FIG. 4.

Further, the results of the experiment shown in FIG. 7 confirm that the allowable melting temperature of the flow solder can be extended to 260°C at the In content of 7 mass%.

In view of the foregoing results, by cooling the upper surface of the board with the blowing amount of nitrogen at about 1.2 m^3/min and using the heat dissipation jig, it is possible to conduct flow soldering by using the Sn-Ag-Cu solder melting at 250°C even in a case of adding In by the amount of about 9% to the reflow solder for the surface mounting component. In short, according to the fourth example, the amount of In that can be added to the solder for the surface mounting component can be increased up to about 9% in a case of conducting flow soldering by using the Sn-Ag-Cu solder melting at 250°C, which can sufficiently cope with the low heat resistant electronic component with ease.

[Fifth Example]

In a fifth example, the effect of suppressing peeling caused by segregation in the surface mounting component upon flow soldering is improved by making the lead plating Pb-free for the surface mounting component to be reflow soldered in the first example.

In this case, the molten solder in the flow soldering bath (not illustrated) was Sn-0.8Ag-57Bi, Sn-0.7Cu or Sn-3Ag-0.5Cu (unit: mass%) approximate to an eutectic composition,

and the temperature of the flow soldering bath was set to several conditions such that the temperature was 235 to 280°C.

Each of the samples described above was observed whether the breakage occurred or not in the connection portion of the QFP-LSI 2a.

FIGS. 8 and 9 show the results of the experiment for the cases of Sn-3mass%Bi plating and Sn plating, respectively, as the fifth example. In FIGS. 8 and 9, the temperature of the molten solder in the flow soldering bath is indicated on the abscissa and the In content in the solder used for the connection of QFP-LSI is indicated on the abscissa. In addition, the condition not causing breakage is indicated by symbol "○" and the condition causing the breakage is indicated by the symbol "X". Further, the solid line in each of the figure is a line considered to be a boundary between the conditions causing breakage and the conditions not causing the same.

For comparison with the results of the experiment in FIG. 4 (using Sn-10Pb plating), the boundary in FIG. 4 is shown by the dotted line in FIG. 8. Further, for comparison with the results of the experiment for FIG. 8 (using Sn-3Bi plating), the boundary in FIG. 8 is indicated by a dotted line in FIG. 9.

The results show that the amount of In that can be added to the solder for the surface mounting component is

about 8% in a case of using Sn-3Bi plating (FIG. 8) when flow soldering is conducted by the Sn-Ag-Cu solder, etc. melting at 250°C. Further, the results show that the amount of In that can be added to the solder for surface mounting component is about 9% in a case of using Sn plating (in FIG. 9) when the soldering is conducted by the Sn-Ag-Cu solder melting at 250°C. However, in a case of conducting flow soldering using the Sn-Ag-Cu solder, etc. melting at 260°C, the amount of In that can be added to the solder for surface mounting component is decreased to about 5%.

As has been described above, according to the fifth example of making the lead plating Pb-free for the surface mounting component, the amount of In that can be added to the reflow soldering can be about 8 to 9% without cooling by the board cooling device 6, which can sufficiently cope with the low heat resistant electronic component with ease.

[Sixth Example]

In a sixth example, the effect of suppressing peeling by segregation of the surface mounting component upon flow soldering is improved by making the lead plating Pb-free for the surface mounting component to be reflow soldered in the fourth example.

In this case, the molten solder in the flow soldering bath (not illustrated) was Sn-0.7Cu (unit: mass%) and Sn-3Ag-

0.5Cu (unit: mass%) approximate to an eutectic composition, and the temperature of the flow soldering bath was set to several conditions such that the temperature was 250 to 280°C.

Each of the samples described above was observed whether the breakage occurred or not in the connection portion of the QFP-LSI 2a.

FIG. 10 shows the results of the experiment for the sixth example. In FIG. 10, the temperature of the molten solder in the flow soldering bath is indicated on the abscissa and the In content in the solder used for the connection of QFP-LSI is indicated on the abscissa. In addition, the condition not causing breakage is indicated by the symbol "○" and the condition causing the breakage is indicated by the symbol "X". Further, the solid line in FIG. 10 is a line considered to be a boundary between the condition causing breakage and the condition not causing the same. For comparison with the results of the experiment for FIG. 9 (using Sn plating and using neither cooling the upper surface of the board nor the heat dissipation jig), the boundary in FIG. 9 is shown by the dotted line in FIG. 10.

As shown in FIG. 10, according to the sixth example, the amount of In that can be added to the solder for the surface mounting component can be about 9% also in a case of conducting the flow soldering by the Sn-Ag-Cu solder melting at both temperatures of 250°C and 260°C, consequently which

can sufficiently cope with the low heat resistant electronic component.

Industrial Applicability

According to the invention, soldering of a low heat resistant electronic component such as FPGA to a circuit board can be attained by using a Pb-free solder alloy.